WE CLAIM:

1.   An optical code scanner employing a laser beam projected from the scanner along a propagation axis to scan optical code symbols wherein the laser beam has

a central peak which diverges and

a wave front which is generally conical near the propagation axis and flattens with increasing distance from the optical axis.

2.   The scanner of claim 1, wherein the laser beam is elongated in a direction perpendicular to the optical axis.

3.   The scanner of claim 1, wherein a donut distance Z_{max} of the beam is greater than a maximum working distance of the scanner.

4.   The scanner of claim 1, wherein the laser beam has an essentially infinite donut distance Z_{max}.

5.   The scanner of claim 3, wherein the beam produces a spot at a minimum working distance of the scanner which has a dimension d_0 in the direction of scanning less than 13 mils and a dimension d greater than 160 mils at a maximum working distance of the scanner.

6.   The scanner of claim 3, wherein the scanner is capable of using the laser beam to read 7.5 mil code at a minimum working distance of less than 9 inches and to read 100 mil code at a maximum working distance greater than 540 inches.

7. A laser beam for use in scanning bar codes having a wave front which deviates from a reference plane perpendicular to the axis of propagation, the deviation being characterized by the formula

$$W(r) = \alpha r - \beta r^2$$

wherein $W(r)$ is the deviation;

wherein α is selected to produce a spot at the minimum scanning distance with a diameter d_0 sufficient to permit the reading of the highest density bar code to be scanned; and

wherein β is selected to provide optimum working ranges for bar codes of different densities.

8. The laser beam of claim 7, wherein α is between $0.2 \cdot 10^{-3}$ and $6 \cdot 10^{-3}$ mm^{-1}.

9. The laser beam of claim 8, wherein $\beta < 2\alpha / R_0$ where R_0 is the system aperture.

10. An apparatus for scanning an optical code comprising a source of a scanning laser beam for directing the laser beam toward the optical code to be scanned and causing the beam to move along a scan line; and a light detector for receiving light reflected from the optical code, wherein the source of the laser beam includes a laser diode and an optical system positioned with respect to the laser diode and configured to produce a generally conical-shaped wave front in the laser beam and a central spot which increases in area with distance from the scanning apparatus.

11. The apparatus of claim 10, wherein the optical system includes at least one optical element for partially collimating the laser beam, and imposing a

generally conical wave front deformation on the laser beam directed toward the optical code.

12.   The apparatus of claim 11, wherein the optical system includes a plano convex lens for partially collimating the laser beam and an optical element having a substantially flat first surface perpendicular to the optical axis of the system and a second surface defined by a figure of rotation formed by rotating a line about said optical axis at an acute angle with respect thereto, thereby defining an optical element which causes a phase tilt in the beam inward toward the optical axis.

13.   The apparatus of claim 11, wherein the optical system includes a collimating lens, a lens providing magnification to cause divergence of the resulting scanning laser beam, a linear axicon lens to produce the conical wave front deformation in the laser beam and an aperture limiting the radial extent of the scanning laser beam.

14.   The apparatus of claim 11, wherein the scanning laser beam has a transverse field distribution that can be expressed as a series containing Bessel functions and wherein essentially only a central peak is employed for scanning.

15.   A method of producing a laser beam for scanning an optical code comprising:

(a)   providing a diverging laser beam from a laser diode;

(b)   reducing the divergence of laser beam to a predetermined non-zero divergence, and

(c)   imposing a generally conical wave front deformation on the beam;

wherein the steps (b) and (c) can be performed in any order or simultaneously, and wherein a diverging, nearly diffraction free laser beam is produced for scanning optical code.

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16.   A method of scanning a symbol comprising:

(a)   generating a beam of laser light;

(b)   modifying the beam of light to create a beam which has a generally conical wave front and an intensity profile along a line perpendicular to

10   the axis of propagation characterized by the central peak and a plurality of secondary peaks symmetrically located on either side of the central peak and which central peak has a diameter which increases as a function of distance from the scanner; and

(c)   moving the modified beam across the symbol to be read.

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17.   The method of claim 16, wherein the central peak has a diameter which increases as a function of distance from the scanner by a factor of between 0.2×10^{-3} and 6×10^{-3} per mm of distance projected.

20   18.   Laser scanner apparatus for producing a laser beam with an elongated spot for scanning a symbol comprising:

a source of a laser beam; and

an optical system for splitting the laser beam from said source and directing portions of the split beam toward the symbol, centers of said beam

25   portions being displaced from one another along an axis perpendicular to a direction of scanning of the laser scanner apparatus to produce thereby an elongated region of illumination on a reference plane perpendicular to the beam portions in at least part of a working range of the laser scanner apparatus.

19. The apparatus of claim 18, wherein the beam portions are sufficiently displaced so that they have minimum overlap.

20. The laser scanner apparatus of claim 18, wherein the optical system is single period diffraction grating with a cosine-shaped profile.

21. The laser scanner apparatus of claim 20, wherein the grating phase is given by the expression

$$W(y) = W_0 \cdot \cos(\frac{y}{A} \cdot 2\pi)$$

wherein y is the dimension along the axis perpendicular to the direction of scanning, A is a vertical aperture of the system and W_0 is the amplitude of the grating phase.

22. The apparatus of claim 18, wherein the optical system includes an optical plate having two planar refractive surfaces which are non-parallel and from each of which a portion of the laser beam is propagated.

23. The apparatus of claim 18, wherein the optical system includes a partially reflective plate having two planar reflective surfaces from each of which a portion of the laser beam is propagated.

24. A lens system for an apparatus for providing a laser beam for scanning optical codes, the lens system comprising:
    a glass lens with at least one spherical surface; and
    a molded plastic element having a non-planar refractive surface located on an optical axis of the glass lens, which in combination with the glass

lens provides an aspherical lens system with greater temperature stability than an optically equivalent aspherical plastic lens.

25. The lens system of claim 24, wherein the plastic element includes at least one surface configured as an axicon.

26. The lens system of claim 24, wherein the molded plastic element provides a phase plate.

27. The lens system of claim 24, wherein the molded plastic element provides an aberration correction for the glass lens.

28. The lens system of claim 24, wherein the molded plastic element further comprises an integral plastic sleeve for assisting in retaining the glass lens in position in the lens system.

29. An athermalized laser assembly comprising:
a laser diode;
a lens system;
a first member for maintaining the relative positions of the diode and lens system having a first coefficient of thermal expansion and effective length L in the direction of an optical axis of the laser assembly; and
a second member having a second, larger coefficient of thermal expansion and an effective length L_p in the direction of the optical axis of the laser assembly, the first and second members together confining the separation between the laser diode and lens system to a desired spacing along the optical axis of the assembly, wherein the lengths L and L_p and the thermal properties of the members are selected so that linear expansion of the second member in one direction along

the optical axis of the assembly substantially cancels out the linear expansion of the first member in the opposite direction along the optical axis of the assembly.

30. The laser assembly of claim 29, wherein the first member is a tube and the second member is a cylindrical sleeve.

31. The laser assembly of claim 30, wherein the lens system includes a glass lens and further comprising a spring located in the tube for maintaining the glass lens in contact with the sleeve.

32. The laser assembly of claim 30, wherein the tube is made of metal and the sleeve is made of plastic, and the tube and sleeve are arranged in telescoping fashion.

33. The laser assembly of claim 30, wherein the lens system includes a lens element integral with the sleeve.

34. The laser assembly of claim 33, wherein the lens element integral with the sleeve provides an aberration correction.

35. The laser assembly of claim 33, wherein the lens element integral with the sleeve has a linear axicon surface.

36. The laser assembly of claim 33, wherein the lens element integral with the sleeve provides a single period diffraction grating with a cosine-shaped profile.

37. The laser assembly of claim 36, wherein the lens system includes a lens with at least one spherical surface and wherein the lens element integral with

the sleeve provides a linear axicon surface and a single period diffraction grating with a cosine-shaped profile.

38.   The laser assembly of claim 37, wherein the laser diode and lens system are positioned with respect to one another and configured to reduce the divergence of the laser beam produced by the laser diode and to produce a nearly diffraction free beam having an elongated region of illumination on a reference plane perpendicular to the laser beam within a working range of said laser assembly.